WP T2 – INNOVATION ON TEXTILE WASTE MANAGEMENT

ACTIVITY A.T2.3 PILOT CASES

D.T2.3.2 PILOT CASES

Partner:
PP 7 INOTEX Ltd. (INOTEX)
(Czech Republic)

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ENTeR - Expert Network on Textile Recycling

ENTeR works in five central European countries that are involved in the textile business, to promote innovative solutions for waste management that will result in a circular economy approach to making textiles.

The project will help to accelerate collaboration among the involved textile territories, promoting a joint offer of innovative services by the main local research centres and business associations ("virtual centre"), involving also public stakeholders in defining a strategic agenda and related action plan, in order to link and drive the circular economy consideration and strategic actions.

The approach of the proposal and the cooperation between the partners is oriented to the management and optimization of waste, in a Life Cycle Design (or Ecodesign) perspective.

CONTENT

1. Pilot case description – aim and scope

1.1. Introduction

“Reduction of the waste generation through prolongation of the service life of textile products”

The pilot case aims to compare the length of the service life of textiles from 100% cotton and from the cotton/PES blends used for hospital service textiles which are designed for the repeated washing. The aim is to demonstrate the prolongation of the service life in case of textiles made from blends and therefore the reduction of raw materials consumption and thereby reduction of amount of generated textile waste (end-of-life textile products).

Relating to the large-scale use of these textiles for medical facilities, there is an opportunity to reuse and recycle these relatively well-defined materials after their physical lifetime. For pilot verification of this direction, it is necessary to create mutual coordination between producers (textiles and protective clothing or bedding), users and, increasingly, industrial laundries offering the rental of these products. Besides the ecological effect and the step towards the sustainability of the material resources, this cooperation may bring additional economic effects; instead of the upcoming landfill and liquidation charges, to create prerequisite for partial compensation of acquisition costs through the recovery of waste in the circulating economy.

1.2. Aims of the study

The main aim of this study is to map the issue of textile waste from industrial laundries processing the linen from healthcare sector. The partial aims that will help to achieve the main aim will be:

- formulation of a questionnaire and completing it by industrial laundries, which will allow input of the information for the study. In order for laundries to be able to objectively fill out the questionnaires, only those who provide leasing of healthcare linen and thus they have the necessary data will be addressed.
- analysis of the quantity and fibre composition of textile waste from laundries processing linen from healthcare facilities
- discussion of the influence of fibre composition and type of linen from healthcare facilities on the amount of waste (or on the lifetime of linen)
- discussion of the influence of technology that processes linen from healthcare facilities on the amount of waste (or on the lifetime of linen)
- comparison of lifetime of 100 % cotton and blended fabrics (cotton / polyester at different percentages)
- a description of the criteria and system for the disposal of linen and methods of textile waste disposal.

Because the laundry sector is a little bit far from the textile technology industry, the study also includes a basic introduction to laundry processing and technical equipment.

2. Theoretical part

2.1. Introduction

Nowadays, the eco-friendly way of our lives is current and very often discussed topic, which is widespread among all fields and branches. Of course, maintenance of textile in industrial laundries is not the exception from this point of view and ecological conception plays also the important role here. Generally, it means the effort of ensuring the longest lifetime of linen which has undoubtedly a positive effect on the reduction of waste. This can be reached by usage of professional equipment throughout all steps of laundry processing and high-quality chemicals, technical know-how and last but not least repairing of smaller damages which enables re-use of laundry.

Textile waste reduction includes the complex approach to the problem. Not only usage of high-quality textiles has an impact on textile lifetime, but also there is a need to take into consideration a way and system of laundry processing. This must be performed by the fully qualified person with experiences in the field of device equipment, textiles, chemical agents and of course personal interest on effectivity and sustainability of whole process is indispensable.

Nowadays, modern industrial laundries and their customers are turning still more and more to the textile leasing. It is a mutually beneficial cooperation, where the textile is owned by the laundry and is rented to the customer (e.g. a healthcare facility or hotel) together with all the services ensuring its maintenance and distribution. In own interest, the laundries purchase the highest quality textiles and try to minimize their damage during processing. Of course, there is also either own or subcontracted repair of linen leading to a reduction of the amount of discarded laundry. In addition, there are also other options. That is, the textile is owned by the hotel, hospital, etc. and it then uses its own or external laundry to process the linen. It is obvious, however, that the such system will no longer support the use of quality textiles and the pursuit of the gentlest way of linen processing ensuring the longest lifetime of the textiles. Rather, this type of contract could support a reduction in the initial investment costs of purchasing large volumes of laundry, resulting in lower quality.

It should also be added, that the rental of textiles is also a 'waste-free' solution for industrial laundry customers, since the responsibility for disposal and its environmental footprint is taken over by the laundry. And the use of linen leasing seems to be the best way how to reduce textile waste from industrial laundries.

2.2. Laundry and Drycleaners market in the Czech Republic

Czech Laundry and Drycleaners Industry has a long tradition and is well known for high quality of provided services. In the nineties of twentieth century there was a big reduction in the branch caused by an extinction of post-communist organisations which were not be able to keep their competitiveness as well as by changing demands especially for services provided to the customers. The entire industry has been restructured which caused concentration of orders to midsize and big companies, which compete regionally, supra-regionally but also deliver their services outside of the Czech Republic. Gradually, the market for textile renting began to develop, and its share is growing every year in all areas of laundry services – healthcare sector,

food processing, workwear and hotels rental sector. Another situation is in the drycleaning sector, which has experienced with a big change in the demand for services. Many small, often family-owned companies operate in the Czech Republic in the field of textile drycleaning. There are also some foreign companies which are operating a chain drycleaning shops f.e.g. 5 á sec, Penguin e.t.c. Recently, especially in some large cities, there is also a trend of intermediary companies which provide washing and ironing services according people´s time requests. However, these organizations do not operate their own laundries or dry cleaners, they are tied to existing organizations and provide services to the population in the form of picking up dirty and delivering clean laundry according to the customer's preferences.

In 2018, the Czech Technology Platform for Textiles and the Association of Laundries and Drycleaners of the Czech Republic, made historically the first survey of the laundry and cleaning market, which brought basic information about the sector. The survey was conducted in December 2018 by a company Brand Brothers s.r.o. The survey includes companies with following parameters:

- Field of activity in laundries and drycleaning sector
- Annual turnover over 1 million CZK

The results of the survey provided a more specific description of the field as follows:

- In the branch is approximately 8 290 employees
- 52 % companies employ up to 5 employees, 21 % companies employ 5 – 10 employees and 28 % companies have more than 11 employees
- 20 % of companies employ foreign workers, but their share is small - an estimated 4.8 %
- The average wage of management is CZK 23 764
- The average wage of ordinary employees is CZK 16 193
- Most of the companies are working on one shift (68 %) basis, approximately a quarter of the companies' work on two shifts (26 %), 3 % of the plants works on the three shifts and the remaining 3 % have a different shifting mode
- The total daily capacity of the sector is 1 630 t. 60 % of the laundries is with daily capacity up to 1 ton. 1,1 – 5 ton of laundry could be processed in 18 % of the companies and more than 5 ton per day can be processed in just 14 % of the organizations in the field.
- Companies provide laundry services are bigger than companies provide a drycleaning services. Laundries employ on average 13 people.
- In the field is dominating laundry washing service. On the entire washing and cleaning market, washing accounts approximately 85 % of capacity on average.
- The market is strongly concentrated. 15 % of the largest companies' accounts for 90 % of total capacities.
- In average laundries and drycleaners provide its services in 66 % to private companies, in 29 % to households and 17 % to government agencies.
- Textile renting is mostly used in the tourism sector (almost 100 % of orders in 17 entities, up to 40 % in others). Manufacturing companies use the rental of workwear as the second most important group (2 companies rent clothes only to these customers, in one company orders from manufacturing companies make up 81-99 % of all turnover. In other 2 laundries / dry cleaners then from 21-60 %). Medical facilities generate 61-99 % of the total volume of laundry rental orders for 3 companies, up to 40 % for two companies.

	Average share of orders
Hotels and accommodation facilities	82 %
Manufacturing companies	77 %
Health and social care facilities	59 %
Households	1,0 %
Other	10 %

Table No. 1 Share of the sectors using textile leasing (Market Research in the Laundries and Drycleaners Sector, 2018 [(1)])

- The branch is modernized to a large extent, 44 % of companies use machinery 5.1-10 years old, 26 % of companies use equipment up to 5 years of age, 28 % of plants are equipped with equipment aged 10.1-20 years. Only 3 % of companies use machines older than 20 years.
- Most companies in the industry use solo machines (87 %) for washing. 12 % of companies use tunnel washing lines in addition to solo machines.
- The average water consumption per kilogram of washed laundry is 15 litres for solo machines, 7 litres for tunnels. The combined consumption is 9 litres per kg of laundry.
- Laundries use different environmental measures – 27 % recycle water, 22 % firms recuperate heat. Approximately 14 % use other measures - waste treatment equipment, waste-free distillation equipment, water collectors, photovoltaic panels, etc.
- Dry cleaning services create approximately 15 % of the entire laundry market.
- On average, the drycleaning shops employ only 3 employees in one establishment.
- Dry cleaning shops use in 95 % perchlorethylene for dry cleaning, only 5 % of subjects use alternative solvents.
- 51 % of companies that offer textile cleaning use both chemical (“dry” cleaning) and wet cleaning.

2.3. Linen from healthcare sector

2.3.1. Medical textiles

The hospital clothing, beddings, towels etc. are made from 100% mercerised cotton (about 36,9% of textiles volume), from 100% PES (24,1%), from blend PES/ba 65/35 (about 20,2%), 16,5% are made by products from 50/50 cottton/PES; share of other fibers on Czech market is only 2,1%. [(2)]

In the production of medical textiles (surgical textiles, medical clothing and bedding etc.), new technologies and materials are increasingly being used, expanding their range of utility properties. The fieald of medical textiles has been developing dynamically in recent years, both in the area of non-woven materials and in the area of materials intended for repeated use.[(3)]

The textiles for medical sector may be described in certain following categories. [(3)]

a) Surgical textiles [(3)]

In general, two groups of materials are used: *microfiber* is a densely woven fabric made of fine polyester fiber bundles with a fluorocarbon barrier finish. The carbon or silver fibers may be woven into the fabric. The grammage of the fabrics is chosen according to the purpose; the lower ones have fabrics for production of coats and surgical clothes for clean rooms, the higher weights have the fabrics intended for production of surgical drapes. Very lightweight materials are used for coats over the back with undercut arms, which increases comfort especially for long-term operations. The *trilaminate* materials are designed especially for critical areas of sheats and drapes for high risk operations; it is a three-layer fabric with an intermediate microporous membrane between two layers of polyester fabric.

The polyester knit ha to fulfil a dual role: the upper layer shall absorb and regulate the fluids, the lower layer ensures user comfort. The pores in the membrane are vapour permeable, but at the same time they prevent the penetration of bacteria, viruses or fluids. Some membranes, due to their elasticity, retain the desired barriers properties even after perforation with an injection needle up to 0,9 mm in diameter.

The surgical drapes made from the above mentioned materials are adapted to the individual requirements of the user. by their shape and accessories. They are not "small" and "large" drapes known from the cotton program, but they are drapes including holes, leg sleeves, elastic cuffs and the like; the drapes are fixed to the patient's body with adhesive tapes that are removed during the washing process.

A special category is the so-called *surgical clothing for clean rooms*. It includes the operating blouses and pants for personnel in those operating theaters where maximum cleanliness of the environment is required. These garments are made of fine polyester microfibre with interwoven carbon or silver fiber and are characterized by minimal dustiness and the ability to minimize the risk of contamination of the surgical wound by staff scalp. They may be completed with cuffs made of polyester fiber. [(3)]

b) Medical clothing and hospital bedding [(3)]

The increasing percentage of a working clothes of medical staff and patients is made from mixed fabrics with varying proportions of man-made fiber. With the appropriate choice of materials and their treatment, high comfort is maintained, the products have a longer service life and lower processing costs, which brings considerable savings. Blended fabrics are also used for production of sheets and beddings.

An interesting group of hospital textiles are the sheets made of blended knitts. They are characterized by bidirectional elasticity, so that they perfectly adapt to any mattress, even in the extreme positions of the slats, which is not possible with woven sheets. They have a long lifetime and lower processing costs, they are comfortable for both patients and staff, who significantly facilitate the work in the care of the bed.

To the woven or knitted substrate can be applied the additional materials such as vinyl or polyurethane , to enrich textiles with new properties. For example, a polyurethane coating provides to a fabric a fluid leakage resistance while maintaining vapor permeability. These materials are used in the manufacture of protective mattress covers, washable bedding or absorbent pads.

The man-made fibers also have ane advantage, which is unfortunately so far neglected in our country, which is non-flammability. For example, in the UK, which is known for its stringent fire resistance requirements for both healthcare and social care materials, materials made from man-made fibers are used to make bedding and patient clothing .[(3)]

2.3.2. Technical requirements for textiles for healthcare

Linen for the healthcare sector represents a wide range of textiles with different uses. These include bedding, towels and personal and patient clothing. This laundry is heavily stressed not only when it is used in healthcare facilities or social services, but also when it is processed in industrial laundries. Only quality linen is able to withstand the demanding conditions to which it will be exposed. Technical specification ČSN P CEN / TS 14237 Textiles for healthcare and social service facilities (ČSN P CEN / TS 14237, 2017) recommends characteristics, test methods and minimum performance specifications for unused textiles for healthcare and social service facilities (hospitals, residential care homes, etc.), to give guidance on the suitability of products intended to be maintained by industrial laundering. In addition to this technical specification, there is also the Industry Specification OS 80-07: 2018 + Z1 Textile for Healthcare and social services facilities - Technical Requirements (OS 80-07, 2018) issued by the Textile Testing Institute, s.p. Brno, which also provides an aid in the selection of textiles and textile products for healthcare, which are intended for maintenance in industrial laundries. OS 80-07 serves as a guideline for determining whether a product is suitable for maintenance by disinfectant technological washing procedures in industrial laundries and provides minimum requirements for the purchase of these textile products. It also contains stricter requirements for the properties of textile products, which are specified in ČSN P CEN / TS 14237. The aim of OS 80-07 is to ensure, together with CEN / TS 14237, the suitability of the products for their intended use.

2.3.3. Technical requirements for surgical textiles

The Technical Specification ČSN P CEN / TS 14237 and OS 80-07 are not applicable to surgical textiles under the Class I of the Medical Device Directive (CE marking) nor protective clothing under the PPE Directive. Surgical textiles (drapes, gowns and clean air suits) are subject to much greater demands because it is necessary to ensure the safety of both patients and surgeons. The requirements for this type of textiles are given in the standard ČSN EN 13795 + A1 (ČSN EN 13795 + A1, 2013). In addition to physical parameters such as tensile and bursting strengths and liquid penetration, the resistance to dry penetration of microorganisms (simulation of penetration of dust particles contaminated with microorganisms through gowns or drapes to skin and air) and the resistance to wet microbial penetration (simulation of blood and other body fluids contaminated with microorganisms through gowns or drapes to skin) and linting of material (measuring of particles released from textiles into the air, which are of such a size that they can carry microorganisms).

2.3.4. Hygiene measures and requirements for healthcare linen

There are special requirements for linen from healthcare sector because of its intended use. In particular, there are hygienic cleanliness together with preventive measures in laundry processing that aim to ensure the safety of patients and clients, prevent the spread of diseases and prevent the emergence of resistant bacterial strains. Decree No. 306/2012 Coll. on the conditions and preventing the spread of infectious diseases, and hygienic requirements for the operation of medical facilities and social care institutions (Decree No. 306/2012 Coll.), requires, inter alia, that the washing procedure and process result in linen free of chemical and bacterial contamination. In the field of medical linen, the hygiene is a priority that is strictly monitored. Therefore, the laundry that processes medical and social clients' linen, measures must be taken to decontaminate and return the linen without microbial contamination in the maintenance process. Even in its own interest, the hospitals also carry out their own sampling to determine if the microbiological level of the linen is correct and that there are no pathogenic microorganisms on the linen.

Czech laundries show that the requirements of the above mentioned Decree have been met by a certificate issued by the Association of Laundries and Dry Cleaners (APaČ) after meeting the requirements specified in the Industry Specification OS 80-01 Washing - Professional treatment of laundry from health and social care facilities (OS 80-01:2016, 2016)[32] issued by the Textile Testing Institute, s.p., Brno. The standard that also addresses how to ensure microbiological cleanliness of laundry in the textile washing area is EN 14065 Textiles - Laundry processed textiles - Biocontamination control system (EN 14065, 2017), also known as "RABC". In addition, it is a common practice for laundries to have a certified quality management system (ISO 9001) and environmental protection (ISO 14001).

In other European countries, the emphasis is also placed on the microbiological quality of linen and certification according to EN 14065 (RABC) is common. Of course, some countries also have their requirements for the processing of linen from healthcare facilities, similar to the Czech Republic's Industry Specifications. E.g. Germany has RAL-GZ 992-2, which sets requirements for medical linen.

As mentioned before, the laundry that meets the requirements of the Industry Specification OS 80-01 also fulfills the conditions for washing laundry from medical facilities and social care institutions pursuant to Annex 5 of the Decree of the Ministry of Health No. 306/2012 Coll. OS 80-01 lays down rules and requirements for the process of linen washing and its distribution between laundry and medical or social services facilities. Specifically, it deals with operational requirements for:

- laundry operation (e.g. organization of operations, ventilation, container and cage disinfection facilities, sanitary requirements, hygiene plan, etc.)
- used linen (collecting, storage, sorting, etc.)
- washing of linen (requirements for process water, washing machines, washing process and quality of washing)
- clean linen (drying, ironing and finishing, storage and shipping of clean linen)
- sanitary measures (for areas, process water, technological and handling equipment, personnel, handling of clean laundry and air)

Furthermore, the laundry must ensure a hygienic-epidemiological inspection in laundry according to OS 80-05 (OS 80-05: 2015, 2015) at least once per year. It is a microbiological check to verify the level of microbiological purity of all important and critical points – i.e. process water, process and handling equipment, staff hands, linen in all processing steps, with the greatest emphasis on the linen in shipping and air. An imperative part of the inspection is also a check of the disinfection efficiency of washing machines using biological indicators. OS 80-05 specifies the methodologies and test procedures to be used during inspections and also establishes limit values to be met.

2.4. Laundries technology used in the Czech Republic for processing medical linen

The process of maintaining laundry in industrial laundries is not just about washing, but involves a number of other steps, such as sorting, drying, ironing (and finishing) and shipping of the laundry. In general, typical laundry maintenance processes a standard industrial laundry can be seen in Fig.No.1.

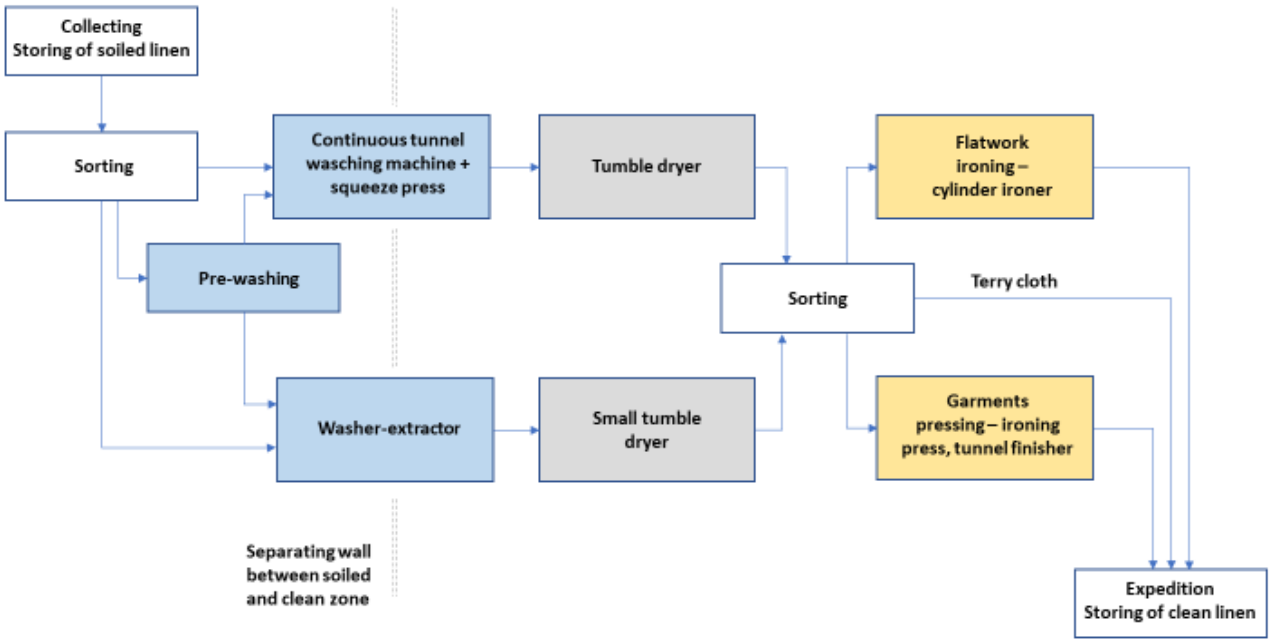

Fig No.1 Typical processes in industrial Laundry (Bobák, 2009)[4] (Leonardo da Vinci Project Sustainability in industrial laundries Module 4)[5]

2.4.1. Washing

Factors influencing laundry performance are described by the Sinner circle, namely: chemical action, mechanical action, temperature effect and time (Sinner, 1960)[6] as you can see in the Fig.2 . If the role of one factor or more factors is reduced (e.g. decreasing of temperature), the reduction must be compensated for by increasing one or more of the other factors (e.g. increasing of chemical action and/or time) to maintain the same level of washing performance (complete circle). Examples are shown in the Fig.2. Nowadays, Sinner circle usually contains also fifth factor – water – necessary and important for washing procedure (Fig.2).

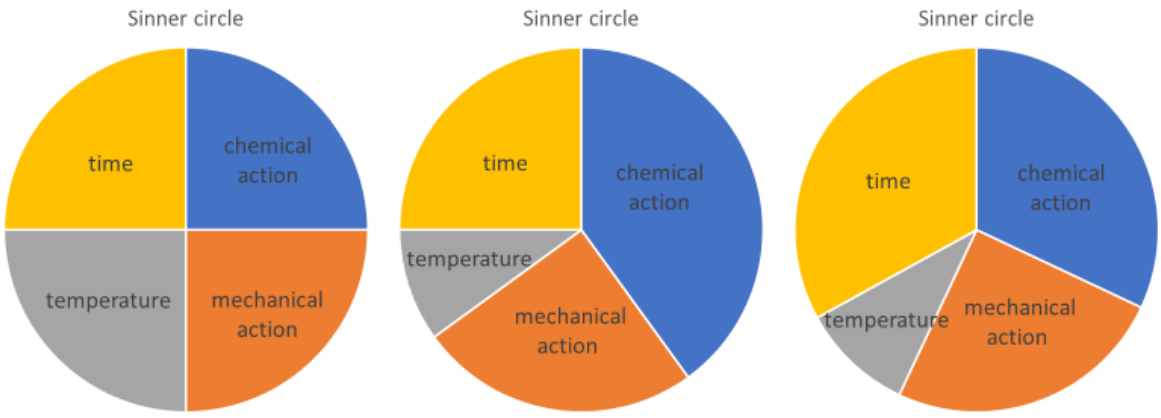

Fig.No.2: Sinner circle and various possibilities increasing or decreasing of the effect of individual factors on the final washing results

Washing in industrial laundries is carried out either in continuous tunnel washing machines or in classical washing machines with spinning (washer extractors).

2.4.1.1. Continuous washing machine

Continuous tunnel washing machine (Fig.3) is the machine designed for washing laundry, where elementary batches progress in a continuous process. The cage of tunnel washing machine is divided into zones: prewash, main washing, rinsing and finishing (e.g. neutralisation or starch). Each zone can consist of several chambers. The tunnel washing machine is followed by a squeeze press. Squeeze press is an equipment used for mechanical dewatering of textiles by compression. They are followed by tumble dryers, which make the laundry loosen up and dry. This whole system is called washing tunnel line. The continuous washing line is therefore a completely integrated system of a series of machines for washing, dewatering and drying individual separate loads, including all necessary equipment for water, steam, gas, electricity and washing and auxiliary agents (ČSN EN ISO 10472-3, 2009)[7].

Fig. No.2: Continuous washing machine (Barabášová, 2015)[8]

Fig.No.3:Squeeze press (Tůma, 2009)[9]

2.4.1.2. Washer-extractor

Washer extractors are used in laundries with a smaller capacity or for less bulky loads of Laundry requiring special washing conditions, ie processing of high quality work clothes, washing heavily soiled laundry, infected laundry, washing laundry from cleanrooms, washing of medical devices, sensitive laundry (wool) or special items (e.g. mattresses). (Leonardo da Vinci Project Sustainability in industrial laundries, Module 3, Chapter 2)[10] (Barabášová, 2015)[8]. Washer extractors are produced in the interleaving version (separate loading and unloading of the washing machine drum, „hygiene washing machine“, where loading is on the unclean side of the Laundry and unloading is on the clean side of the Laundry) or non-interleaving. In praxis, it is commonly referred to as a barrier machine or solo machine (washing extractor).

Fig. No. 4: Washer extractor of company Girbau

The continuous washing line have a capacity of the order 400 to 1000 kg of dry laundry per hour, washer extractors then 7 to 250 kg of dry laundry per cycle. However, the specific water consumption is lower for continuous washing line (3 – 15 l/kg of dry textiles) than for washer extractors (14 – 50 l/kg of dry laundry). This is achieved by recirculation rinsing and pressing water into the prewash and main washing zone (Barabášová, 2015)[8]. In modern tunnel washing lines, pure water is added in one place only (final rinse). In the washing process, rinsing always requires the greatest amount of water. This is because the rinse quality affects the amount and type of laundry residues that can cause skin irritation, unacceptable laundry appearance and ironing problems (Leonardo da Vinci Project Sustainability in industrial laundries Module 2, Chapter 3)[11] (Leonardo da Vinci Project Sustainability in industrial laundries, Module 1, Chapter 2)[12].

2.4.1.3. Disinfecting efficiency of washing

The main wash is always necessarily associated with disinfection in the process of medical laundry processing. This can be divided into thermo disinfection or chemo-thermo disinfection. It can be said that thermo disinfection means washing at a temperature of at least 90 ° C for at least 10 min and chemo-thermo disinfection then washing at a lower temperature (e.g. 60-70 ° C for 15-20 min) using washing detergents with disinfectant effect. The disinfection efficiency of washing can be ensured even at lower temperatures (delicate laundry) using special detergents (e.g. Eltra 40 for washing at 40 ° C).

Each country has different hygienic requirements for disinfection efficiency of washing. In the Czech Republic wash disinfection efficiency is verified using biological indicators according to OS 80-05 Hygiene-epidemiological control in laundry (OS 80-05: 2015, 2015) or OS 80-08 The effectiveness of the washer disinfection program (OS P 80-08, 2018). In practice, the check is carried out by placing the bioindicator (biological indicator) contaminated with the test bacterial strain together with the load in the washing machine (or washing machine chamber) and running the verified washing program. If the bacteria are killed, this means that the program has proven the disinfection efficiency of the wash, if the

strain has survived, the disinfectant effect is not sufficient, therefore the program is not disinfectant.

2.4.1.4. Washing quality control

In the Czech Republic washing quality control is performed using the standard cotton fabric according to Industry Specification OS 80-04 (OS 80-04, 2015). This Industry Specification assesses the quality of washing in terms of the impact of the industrial washing process on the washed textiles. The evaluation is usually performed after 50 wash cycles. The indicators of washing quality are: loss of dry / wet strength, degree of whiteness, basic degree of whiteness, colour shade of whiteness, content of inorganic substances on the textile, event. degree of chemical damage to cotton (evaluation according to RAL GZ 992). In addition, the content of organic substances and ferric ions can also be evaluated. OS 80-04 specifies the required values that a laundry must meet in order to be awarded by industry certification.

2.4.2. Drying

The next step after the washing process is drying the laundry. Dryers in industrial laundries can either be part of a continuous washing line or stand alone. The tumble dryer (FIG. 5), which is part of a continuous washing line, serves to loosen the laundry from the press, pre-dry and dry the laundry completely, and is connected by conveyor belts to the pressing device. Drying itself takes place with heated air (temperature 150-180 ° C). Heating is ensured by steam or gas. The requirements for drying straight and shaped laundry are different, depending on the following method of completion (Tůma, 2009)[9] (Leonardo da Vinci Project Sustainability in industrial laundries Module 2 Chapter 5)[13].

Fig. No. 6: Tumble dryers (Tůma, 2009)[9]

Fig. No. 7: Vacuum conveyor made by Engel Gematex

Compact (freestanding) dryers are designed for drying laundry from washer extractors. They are also suitable for textiles that need to be completely dried (e.g. terry towels, which are no longer ironed). They work mostly with steam heating, but there are also electric ones (Tůma, 2009)[9]. Filling and emptying takes place in small laundries manually, in larger plants by an automatic vacuum conveyor.

2.4.3. Ironing and finishing

2.4.3.1. Ironing of flatwork

A cylinder ironer is used in industrial laundries to iron flatwork. It is a device that removes from laundry remaining moisture and at the same time irons it by pulling it against one or more heated rollers, where it is held by a suitable system (e.g. belts). Usually, the feeding machine is used together with the ironer, followed by a folding machine, which automatically folds flatwork into defined dimensions. The cylinders rotate in steam or gas-heated mangers (ČSN EN ISO 10472-5, 2009)[14].

2.4.3.2. Garments ironing

The tunnel finisher (Fig.8) is a machine for drying and finishing garments (shirts, trousers), inside which the damp clothes are hung on the hangers on the overhead conveyor and conveyed through the machine in an atmosphere of high humidity with subsequent the atmosphere of dry hot air created by the tunnel dryer (ČSN EN ISO 10472-4, 2009)[31]. Heating is provided by steam or gas (Leonardo da Vinci Project Sustainability in industrial laundries Module 2 Chapter 5).

Fig No. 8: Tunnel finisher (Tůma, 2009)[9]

Another device used to iron garments is an ironing press. It is a machine for ironing the fabric by compression between two parts, of which at least one is heated (or equipped with a steaming device) (ČSN EN ISO 10472-6, 2009)[15].

Fig. No.9: Ironing press (Tůma, 2009)[9]

2.5. Detergents used in textile care

The choice of suitable detergents is very important for the correct performance of the washing process. The role of detergent is to ensure the correct water parameters, optimum pH, even wetting of dirty laundry, removal of dust particles, greasy dirt and stains. Equally important are the requirements for whiteness and hygienic cleanliness of the washed laundry. However, the use of detergents can have a negative impact on the environment and durability of the laundry itself. The composition of detergents must comply with national legislation, in particular the content of biodegradable substances and phosphorus (Škrdla, 2014)[16].

Detergents compose of four main building blocks: surfactants, alkalis, builders and performance ingredients.

Surfactants are organic molecules consisting of hydrophobic and hydrophilic parts within one molecule resulting in orienting themselves according to phase boundaries. In detergent they provide very significant roles like swift wetting of the textile, electrostatic repulsion soil removal, soiling matter suspension into the wash batch and increases solubility of oily compounds. Surfactants can be categorized into four categories according to their ionicity:

A) anionic - negatively charged hydrophilic part

B) cationic - positively charged hydrophilic part

C) non-ionic - without ionization in water

D) amphoteric - pH dependent charge

Alkalis are present in the detergent to set the correct pH typically between 10-11 but that's only one of their functions. Alkalis also help with acidic soil neutralization process, prevention of soil redeposition, optimizing bleach and enzyme conditions. Their composition can vary from one commercial product to another but almost exclusively they compose of sodium/potassium salts like sodium silicates, carbonates and hydroxides. Composition of the alkali blends dependent on

use case of the detergent (e.g. - sodium hydroxide is used for heavy levels of soiling while sodium metasilicate is used for medium powered detergents).

Builders are chemicals providing the means of removal of hard water ions like calcium and magnesium which if not removed from wash batch greatly affect the wash performance and the quality of washed fabrics. There are two mechanisms which the builders can utilize. First is ion exchange and second is complexing. Both mechanisms have advantages and disadvantages. For example, the zeolites utilize ion exchange mechanisms and are excellent substitutes for phosphates; on the other hand they provide poor magnesium ion removal. Compared to EDTA (ethylenediaminetetraacetic acid) phosphates utilize complexing mechanism and firmly remove the magnesium and calcium; but there are severe environmental and legislative issues.

Performance ingredients to this category we can add several compounds like Soil anti re-deposition agents suppressing the redeposition potential which would otherwise lead to greying of fabrics. These compounds are based on silicates, PVP (polyvinylpyrrolidone) or polycarboxyles (e.g. carboxymethyl cellulose). Another compounds are optical brightening agents (OBA) often called colourless dyes capable of absorbing ultraviolet light and remitting visible blue light resulting in the white fabrics being visually whiter. OBAs are incorporated into all white fabrics during manufacture but laundry detergents contain OBA to increase the level of OBAs in the fabric. Enzymes are often present in detergents to provide natural catalysts in a progress of breaking of organic molecules. Important part when talking about enzymes is that they are selective, meaning that certain type of enzymes break certain types of organic molecules. There are four types of enzymes: proteases which break down amino-acids, amylases which break down sugars, lipase - break down fatty acids and celluloses which breakdown saccharide groups. Main factors for enzymatic cleaning prices are temperature and pH. Enzymes are useless when there are chlorine release agents present. Oxidizing and bleach activators are present in detergent to achieve effective stain removal. Most commonly used release agents are sodium perborate tetrahydrate, sodium perborate monohydrate and sodium per carbonate and provide best performance in wash temperatures between 80-85 degrees celsius. There are also few less used compounds in detergents worth mentioning like soil releasing polymers, emulsifiers and chelating agents (sodium gluconate) for removal of metal ions like copper, iron and manganese which can destabilise peroxy bleaches and inactivate enzymatic process. (Leonardo da Vinci Project Sustainability in industrial laundries Module 4 Chapter 1, Module 4 Energy, Detergents, Chapter 1).[17]

Basically, three types of detergents are used in laundries - liquid, powder and paste. Powder, liquid or paste detergents - all use fundamentally the same ingredients to achieve expected wash performance.

Industrial laundries use automatic dosing systems. Modern dispensing systems allow automatic dispensing of both powder and liquid detergents. The automatic dosing device reduces the demands on human work, manual handling of chemicals, and ensures accurate repeated dosing and validation process (Škrdla, 2014)[16].

Fig. No. 10: Peristaltic dosing system of Büfa company (www.buefa.ge, 2019)[18)]

In order to wash laundry from medical facilities, it is essential that detergents also have a disinfectant effect. The vast majority of laundries replace thermodesinfection with the chemo-thermo disinfection method. This method makes it possible to reduce the temperature of the washing bath and is nowadays quite common in industrial laundries. Detergents intended for washing laundry from medical facilities are usually certified according to the methodology of the Robert Koch Institute.

2.6. Wastewater

The sources of contamination of wastewater in industrial laundries are as follows:

- detergents and auxiliaries (especially surfactants, bleaching agents, chlorine, alkaline substances and phosphates)
- laundry dirt
- steam used to heat metal-reactive washing machines
- a substance from untreated water containing particles and micro-organisms
- reaction between dirt and additives in detergents or water (Leonardo da Vinci Project Sustainability in industrial laundries Module 1 Chapter 4)[(19)]

In practice, two possibilities of waste water discharge are used. The first option is direct discharge of waste water through the waste water treatment plant into the surface water; the second is indirect discharge through the municipal sewerage system and the waste water

treatment plant into the surface water. There is a number of the requirements; the most important of them are contained in the regulations of most European countries and depends on the way of discharging wastewater.

In the case of indirect discharges, the requirements for waste water from laundries in the Czech Republic are mainly determined by local conditions (according to a National and European requirements), which are specified in the contract with the local sewerage administrator.

The most important monitored parameters of industrial wastewater are pH, maximum water temperature, heavy metals, AOX (absorbable organic compounds containing halogens - Cl, Br, I), BOD (biological oxygen demand), COD (chemical oxygen demand), nitrogen and solid settable substances (Leonardo da Vinci Project Sustainability in industrial laundries Module 1 Chapter 5a)[(20)].

Monitoring the pH of water is very important in laundries, as it can often be very alkaline due to the chemistry used. If the pH is too high, it can damage bacteria in the sewer system and the pipe itself. Likewise, high temperature can lead to corrosion of the pipe. Heavy metals are a problem in general because they accumulate in groundwater and are carried laterup the food chain. However, the problem is especially in industrial laundries that wash work clothes. Chlorine is another hazardous substance. It is very reactive and forms organic chlorine compounds (determined as AOX) in the wash liquor, some of which may be toxic. The formation of AOX depends on the concentration of active chlorine, the chlorine carrier and the organic load of the wash liquor. Laundries therefore seek to replace chlorine with 'chlorine-free' alternatives such as hydrogen peroxide or peracetic acid. Phosphates contained in detergents are also of interest. Different detergents contain different amounts. Too much phosphate in the water leads to eutrophication, more algae is formed, which causes a reduction in the oxygen content of the water and thereby collapses the ecosystem (Leonardo da Vinci Project Sustainability in industrial laundries Module 1 Chapter 4)[(19)].

From an environmental point of view, it is therefore necessary to adjust the pH of the waste water, further remove harmful components, lower the temperature and reduce the consumption of detergents and other chemicals, and preferably uses those which are harmless to the environment. Municipal wastewater treatment plants as well as wastewater treatment systems installed in laundries must ensure the following steps: primary (mechanical) treatment (e.g. removal of large objects and sand), biological treatment (oxidation bed or aeration system, post-precipitation) and chemical treatment (e.g. phosphorus removal) (Leonardo da Vinci Project Sustainability in industrial laundries Module 1 Chapter 5a)[(20)].

Nowadays, various technologies are available for the treatment of waste water from industrial laundries, but of course also for the treatment of recycled water, which is reused during washing. The technologies allow the separation of residual contamination by mechanical impurities, bleaching agents and surfactants. The principle of cleaning consists in chemical stabilization, precipitation, sedimentation or flotation and subsequent filtration and dewatering on the filter press. The pre-treated water is then discharged into the sewage system (https://www.asio.cz/cz/pradelny)[(21)].

2.7. Textile waste from laundries

Waste means, as defined in Directive 98/2008 of the European Parliament and of the Council on waste (Directive 98/2008 of the European Parliament and of the Council), any substance or object which the holder discards or intends or is required to discard. The waste hierarchy of Article 4 of the above-mentioned Waste Directive is as follows:

prevention
preparing for re-use
recycling
other recovery, e.g. energy recovery
disposal

Table No.2: Waste management hierarchy (Directive 2008/98/EC of the European Parliament and of the Council, 2008)[22]

This five-step hierarchy should also be respected in the field of textile waste from the laundry sector. Landfills and incinerators should be the last choice. They should be preceded by the use of textiles, for example, for another customer whose quality requirements are lower, as well as for other industries where the product could be used at least in a lower value application such as cleaning cloths, insulation, etc.

Material reuse and textile recycling have been and is the subject of many research projects that seek and develop opportunities to reduce textile waste.

Thus, in the spirit of the circular economy, we can come across a number of ways of textile reuse. For example, Lindström, which states in its 2015 Sustainability Report that it has established cooperation with the Swedish company Stormie Poodle (a manufacturer of recycled textiles for children's clothing) to use discarded terry fabrics and bedding for the production of children's clothing. In addition, the Sustainability Report of 2017 states that Lindström has opened a production plant in Latvia for the production of garments made from recycled textiles, which, according to the principles of the waste hierarchy, produce garments according to current needs. By 2020, Lindström committed to recycling 90% of textiles (Lindström, 2015)[23] (Lindström, 2017)[24].

2.7.1. Textile dust

In addition to linen, however, we should not forget textile dust in terms of textile waste. In addition to textile waste, this dust presents safety and health problems and risks. Textile dust can cause an explosion quite simply. It has a negative effect on laundry staff, as it can cause respiratory irritation, breathing difficulties, or even asthma. Lung bysinosis, which is professional lung affection in cotton workers, may also occur. Symptomatically in a sensitive individual manifests irritable cough after starting work, the intensity of cough is greater after

the weekend or after vacation. The source of textile dust is mainly natural materials such as wool and cotton (Lai, 2013)[33].

The dustiness in the environment is, of course, monitored and the permissible limits (PEL - permissible exposure limit) are set by the Government Regulation No. 361/2007 Coll. For cotton it is e.g. 2 $mg.m^{-3}$ (Government regulation No 361/2007, Coll.)[25].

3. Catalogue of the waste covered by the pilot case

In general, the hospital service textiles have a simple material composition – mainly 100% cotton, 100% PES (for use in clean air rooms) or blend cotton/PES; the used structures include woven farbics or knitted wear for repeated use and non-woven textiles for disposable textiles. The textiles may include RFID chips for identification of number of the passed maintenance cycles. Also the textiles may be finished by the functional treatment, mostly antimicrobial, flame-retardant, hydrophobic.

The 100% cotton is used only for bedlinen; cotton is inappropriate for use as a barrier fabric because of its high absorption of liquids (blood) and its porosity allowing penetration of skin scurfs and dust from the body of the surgical staff. Co/PES blends used for health care staff clothing and bedlinen show improved wearing comfort properties, better antipilling properties and prolonged service life due to their better mechanical (tensile strength) properties compared with 100% cotton. Compared with pure cotton with the equal fabric construction, the blends cotton/polyester shows much better mechanical performance (strength, abrasion resistivity, lower pills formation) leading to their prolonged service in the long-term maintenance cycles which is important mainly in health-care sector, protective clothing utilizing leasing laundry maintenance (Fig.11).

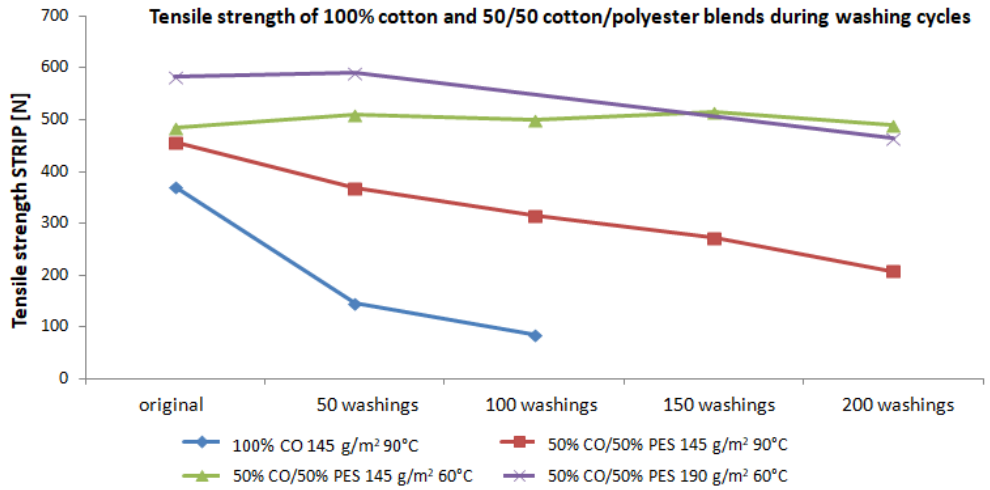

Fig. No.11: Tensile strength (STRIP EN ISO 13934-1) of 100% cotton and blend cotton/polyester 50/50 in during repeated washings at 60°C (+ chemothermo-disinfection) and 90°C (harsh maintenance regimes for health care sector) [26]

The cotton/polyester blends physiological parameters are also advantageous: the cotton part

maintains the high hydrophilicity of the fabric; the polyester part ensures the quick sweat transport resulting in moisture management properties and quick drying effect which are the basic condition of the wearing comfort.

The study focused on the comparsion of these two types of hospital service textiles: made from 100% cotton and from the blend cotton/PES. The studied waste is represented by the end-of-life hospital textiles with this composition: bed linen, staff work clothing and patient´s clothing, surgical textiles.

The detailed characterisation was provided in the Deliverable DT2.3.5 - Pilot Cases – Milestone.

The conclusions of the study showed that 100 % cotton textiles are used in textile leasing sector in minority volume. In four out of five respondents, 100 % cotton underwear accounts for up to 25 % of the volume. Only one company uses mainly cotton. 100 % cotton can be found especially in bed linen, terry program and also as surgical and staff apparel.

From the above answer, it can be concluded that mixed materials dominate in the sector of medical textiles renting. It is not possible to read clearly the three most frequently used material compositions from the answers; in any case, the answers can be summarized by mathematical methods as follows:

- Bed linen is mostly made of a mixture of 80 % cotton, 20 % polyester (on average the material composition is 73.3 % cotton and 26.6 % polyester)
- medical staff's apparel is mostly made of 65 % polyester / 35 % cotton (on average the material composition is 67.75 % polyester and 32 % cotton)
- Patient apparel is made from a mixture of 50 % cotton and 50 % polyester

Surgical textiles are in two cases made of 100 % cotton (once rented laundry and once as a laundry service), in two cases a blend of 65 % polyester and 35 % cotton and once 75 % polyester and 25 % cotton.

4. LCA of the textile waste covered by the pilot case

4.1. Environmental characteristics

The environmental impacts of the industrial rental laundries are linked to consumption of water, energy and detergents, wastewater discharge and textile waste (end-of-life laundry) production. The resulting impacts include water pollution, eutrophication, greenhouse gas emmissions and potential toxicity impacts.[27]

In industrial laundries, the highest consumption of water and energy have the washing lines. According to the benchmark study on industrial laundries sustainability provided by CINET, the study made in 2003 by professor Terpstra from Wageningen University quantified the energy consumption of the industrial laundry process of the corporate hospital clothing washing (tunnel washing, 75°C, heat regeneration, pressurized dewatering) designed to achieve the necessary hygiene standards as 0,30 kg steam and 0,065 kWh electricity per kg laundry; the total energy consumption, converted to MJ/kg, comprised 4,1 MJ/kg [28].

The technology development is aimed at higher efficiency of washing and energy savings. The topic of monitoring water and energy consumption is one of the main arguments in selling of industrial laundry equipment. The continuous washing line – so called tunnel washer – compared to the conventional batch

washing machines have the higher washing efficiency and also more efficient operation in terms of water consumption and energy per kilogram of washed laundry. The usual consumption of batch washing machines ranges from 20 to 50 liters of clean water per kilogram of laundry, while for tunnel washers the consumption normally ranges from 4 to 15 liters per kilogram thanks to the fact that the design of the tunnel washers allows multiple use of water.[29]

Concerning the waste water pollution load, the most important parameters are pH, temperature, heavy metals, AOX, BOD, COD, nitrogen and solidsuspended solids. The details are described in chapter 2.6.

The end-of-service life laundry is decommissioned according to the criteria usually defined by contracts between the laundry and customer (hospital using the rental laundry). The most important parameters for discarding textiles from the use cycle include holes, change of colour shade, stains and the basis weight reduction; the others are number of repairs or achieved limit number of usage cycles. The five industrial laundries participating in a survey within this pilot case study discard nearly 70,000 pieces of hospital textiles per year, which means about 35 tons. This number represents 5-10 % of the total discarded textiles in these laundries. (see the technical report in Deliverable D.T2.3.3_Pilot Cases Technical Report_INOTEX medical textiles).

4.2. Environmental impact assessment

The system covers the following stages:

Extraction of resources: not relevant. The textile is not produced by laundries.
Transport of resources: transport of the laundry from hospitals to the laundry and back.
Storage of resources: storage of the dirty laundry before the mainteance.
Manufacturing, assembly: the washing of the laundry
Storage of finished products: storage of the clean laundry after the washing, before transport back to customer
Use, useful life: use of the laundry in hospitals
Waste transport: transport of the decommissioned laundry; provided by third party
Waste disposal: disposal of the discarded laundry; provided by third party

Process:																
Environmental impact	Energy consumption			Waste generation			Air pollution			Water pollution			Soil contamination / usage			Total
Value of the stage	1 - Process or method with low energy consumption	2 - Average energy consumption	3 - Large consumption	1 - Little waste, no hazardous	2 - Average waste, no specially high volumes or risks	3 - High volumes, also hazardous waste	1 - No air pollution at this stage	2 - Some air pollution, but not considerably high	3 - Considerable air pollution	1 - No water pollution at the stage	2 - Some water pollution under control, (treated)	3 - The process often pollutes water, or high risk of that exists	1 - No potential to contaminate soil	2 - The process potentially pollutes the soil, but it is not likely	3 - Frequent occurrence of normal or accidental soil contamination	Sum up the values in the row
Stages	Before/After			Before/After			Before/After			Before/After			Before/After			

Extraction of resources	n.r./ n.r.	n.r. / n.r.	n.r. / n.r.	n.r. / n.r.	n.r. / n.r.	n.r. / n.r.
Transport of resources	2/2	1/1	3/3	1/1	1/1	8/8
Storage of resources	1/1	1/1	1/1	1/1	1/1	5/5
Manufacturing , assembly	3/3	3/2	1/1	2/2	1/1	10/9
Storage of finished products	1/1	1/1	1/1	1/1	1/1	5/5
Use, useful life	1/1	1/1	1/1	1/1	1/1	5/5
Waste transport	2/1	2/1	2/1	1/1	1/1	8/5
Waste disposal	2/1	2/1	2/1	1/1	1/1	8/5

4.3. Conclusions

As concluded by this pilot case study (see the technical report in Deliverable D.T2.3.3_Pilot Cases Technical Report_INOTEX medical textiles), comparing the laundry with different material composition (mixed X 100% cotton laundry) we can demonstrate that technological process of the maintenance it is almost identical in both cases thanks to the very similar character of these textiles and the large processed loads of laundry. According to the study, both types of laundry are processed at the tunnel washers at bath temperature 60 °C with chemothermal disinfection prevails. Also the used detergents are the same for both types of textile composition.

The results of this pilot case study also clearly showed that textiles with a chemical fibre content (blended materials cotton/PES 35/65, resp. 25/75) have up to 3-times longer life-cycle than 100 % cotton products. According to the results of this pilot study, the industrial laundries offering the leasing laundry services of hospital linen already use these blended materials; as a consequence, the volume of the produced textile waste from the enf-of-service life laundry is reduced in comparison to use of 100% cotton laundry.

Taking into account this fact, we can identify the diferent environmental impact comparing the laundry from 100% cotton and from blended materials (cotton/PES) in terms of volume of the textile waste from the enf-of-service life laundry.

5. Identification of the companies in the partner region with similar waste streams

To prepare a relevant solution concerning industrial companies (laundries) was necessary to map current situation on the market. Therefore, a market survey was prepared, in the field of textile leasing in laundries processing the textile from healthcare sector.

The field of textile leasing in healthcare sector is a very specific and very demanding. Laundries, that supply textiles to a healthcare sector, are required to monitor textile care processing and to keep very strict hygiene and safety measurements to prevent a risk of infections and maintaining safety. These subjects are certified according to Industry Specifications, which clearly define parameters to be met to ensure the safe supply of textiles to healthcare facilities from a hygienic perspective.

There is a total of 13 entities in the Czech Republic that use the certification according to the Industry Specifications. These laundries were selected as suitable subjects for identifying ways of handling textile waste except two companies which do not provide textile leasing (GOLGOT spol. s r.o. and Vít Spáčil – prádelny a čistírny, spol. s r.o.):

TITLE	LOCATION
Fakultní nemocnice Hradec Králové	Hradec Králové
GOLGOT spol. s r.o.	Nymburk
CHRIŠTOF spol.s r.o.	Brno - Komárov
CHRIŠTOF spol.s r.o.	Štětí
Jan Fišer	Česká Třebová
Prádelna Fišer, s.r.o.	Hradec Králové
Prádelna Kyselý, a. s.	Vlašim
PRÁDELNY A ČISTÍRNY, a.s.	Náchod
Praní a Čištění, a.s.	Velká Hleďsebe
RENATEX CZ, a.s.	Ostrava - Poruba
RENATEX CZ, a.s.	Český Těšín
SALESIANER MIETTEX CHEMUNG s.r.o.	Praha - Thomayerova nemocnice
Vít Spáčil – prádelny a čistírny, spol. s r.o.	Prostějov

Table No.3: List of certified Laundries in the Czech Republic (Asociace prádelen a čistíren ČR, z. s. , 2019)[30]

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